Woodrow Wilson International Center for Scholars

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# Inventory of Research on the Environmental, Health and Safety Implications of Nanotechnology

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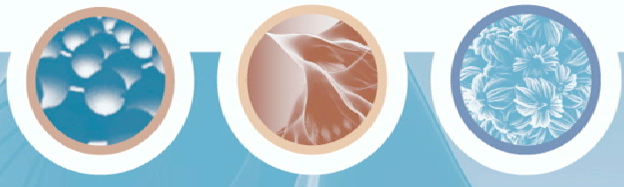

Project on
**Emerging Nanotechnologies**
at the Woodrow Wilson International Center for Scholars

The **Project on Emerging Nanotechnologies** at the Woodrow Wilson International Center for Scholars was created in partnership with The Pew Charitable Trusts.
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**Background**

There is growing consensus that over the coming decades nanotechnology will transform virtually every aspect of people's lives. Numerous nanotechnology products—some estimate over 700—are already on the market and many applications are in the final stage of product development.

With any new technology comes uncertainty. Some of these new nanoproducts or manufacturing techniques may have harmful, unintended consequences. Others suggest great health, environmental and economic improvements over the medical, energy, and industrial applications in use today.

The effort to understand and manage nanotechnology's benefits and risks will be a long, perhaps never-ending one. And while there is currently little evidence that engineered nanomaterials and nano-enabled products will create undue harm, the funding for research and development of nanoscience and engineering applications far outpaces the research on possible human health, safety, and environmental impacts.

To date, no single inventory of government-funded risk research has existed. To fill this crucial gap, the Project on Emerging Nanotechnologies at the Woodrow Wilson International Center for Scholars is compiling an accessible inventory of government-supported research addressing the environmental, human health, and safety (EH&S) implications of nanotechnology.

This inventory is an essential resource for policymakers, researchers, corporations, and others responsible for ensuring nanotechnologies' safe, sustainable development. One critical aim is to facilitate and encourage greater public and private-sector risk-research partnerships, and to foster international research collaborations in the vital area of nanotoxicology and environmental effects.

The first generation of this inventory contains basic information on government-funded, risk-related research projects, including summaries, duration, funding sources, budgets, and, if available, results. The research is categorized on multiple levels. The first layer of categorization analyzes each research project by its relevance to the implications of nanotechnology, whether the nanomaterials under investigation are intentionally manufactured, incidental or naturally occurring, and whether the primary focus is on human health, environment, or safety impacts. A second layer of categorization classifies the research according to its focus within a simplified risk analysis framework. Finally, provision is made for a more detailed, third level of classification according to a range of searchable keywords and phrases. Although not comprehensive, the inventory currently provides the most complete overview of current government-funded research into the EH&S implications of nanotechnology to date.

The inventory is meant to be international and expanding. Every effort is being made to include information on research supported by governments throughout the world. Additions to the inventory will be made as new information is received, and researchers and research managers will be able to contribute new or updated information as their work progresses. Users are encouraged to submit new and updated information to nano@wilsoncenter.org.

The Project on Emerging Nanotechnologies is dedicated to helping ensure that, as nanotechnology research advances, possible risks are minimized, public and consumer engagement remains strong, and the potential benefits of these new technologies are realized.

This inventory is a major initiative to help further and encourage productive private and public-sector EH&S research around the world, and to help create a more complete understanding of how to minimize potential risks posed by emerging nanotechnologies.

The inventory can be accessed online at http://www.nanotechproject.org

**Initial analysis of EH&S research**[1]

As of November 23rd, the nanotechnology EH&S R&D inventory contained information on 208 research projects (figure 1), representing 6 countries and regions, and accounting for over $38 million of research funding annually. 195 projects are funded by governments ($31 million), with the remaining 13 ($7 million) funded by industry or other organizations, or receiving joint funding. There are 169 projects funded in the United States, with the U.S. federal government funding 161 projects for a total of $27 million annually (including an estimated $3 million being spent annually by NIOSH).

The inventory includes information on research on nanostructured materials from a range of sources, and projects with varying relevance to EH&S implications, thus providing a flexible tool for users with diverse interests. Focusing specifically on research into the implications of engineered nanomaterials, there are 85 projects listed, accounting for nearly $14 million in research funds in 2005 (figure 2). U.S.-supported research accounts for over 60% of the projects, while reported research funding is roughly equal between the U.S. ($7 million) and the EU ($6 million).

The majority of these projects are focused on human health effects, with less than half of the listed research specifically addressing environmental impact (figure 3). There are no listed research projects with a specific focus on workplace safety aspects of nanotechnology other than potential health effects.

Focusing on research within the U.S. with high relevance to the EH&S implications of engineered nanomaterials, federal government-funded research accounts for $6 million of the estimated $7 million being spent annually. Research into hazard and exposure (human and environmental) dominate the research portfolio, with research relevant to risk, control, safety and response accounting for approximately 30% of the portfolio (figure 4). While figure 3 shows no listed projects with a specific focus on safety (other than health effects), figure 4 shows that workplace safety-related research is an integral part of a number of projects.

Figure 4 indicates minimal research on controlling exposure to engineered nanomaterials and their release into the environment, as well as very low levels of research into the diseases and environmental impacts that may result from exposure.

Well over 50% of highly relevant hazard research within the U.S. is focused on human health implications of engineered nanomaterials (figure 5), while a little over a third of all hazard research addresses environmental impact. Probing the health-related, hazard research further, nearly three quarters of all research is related to the lungs, with the remaining research projects covering implications to the skin, central nervous system and cardiovascular system (figure 6). There are no projects listed with specific relevance to the impact of engineered nanomaterials to the gastrointestinal tract.

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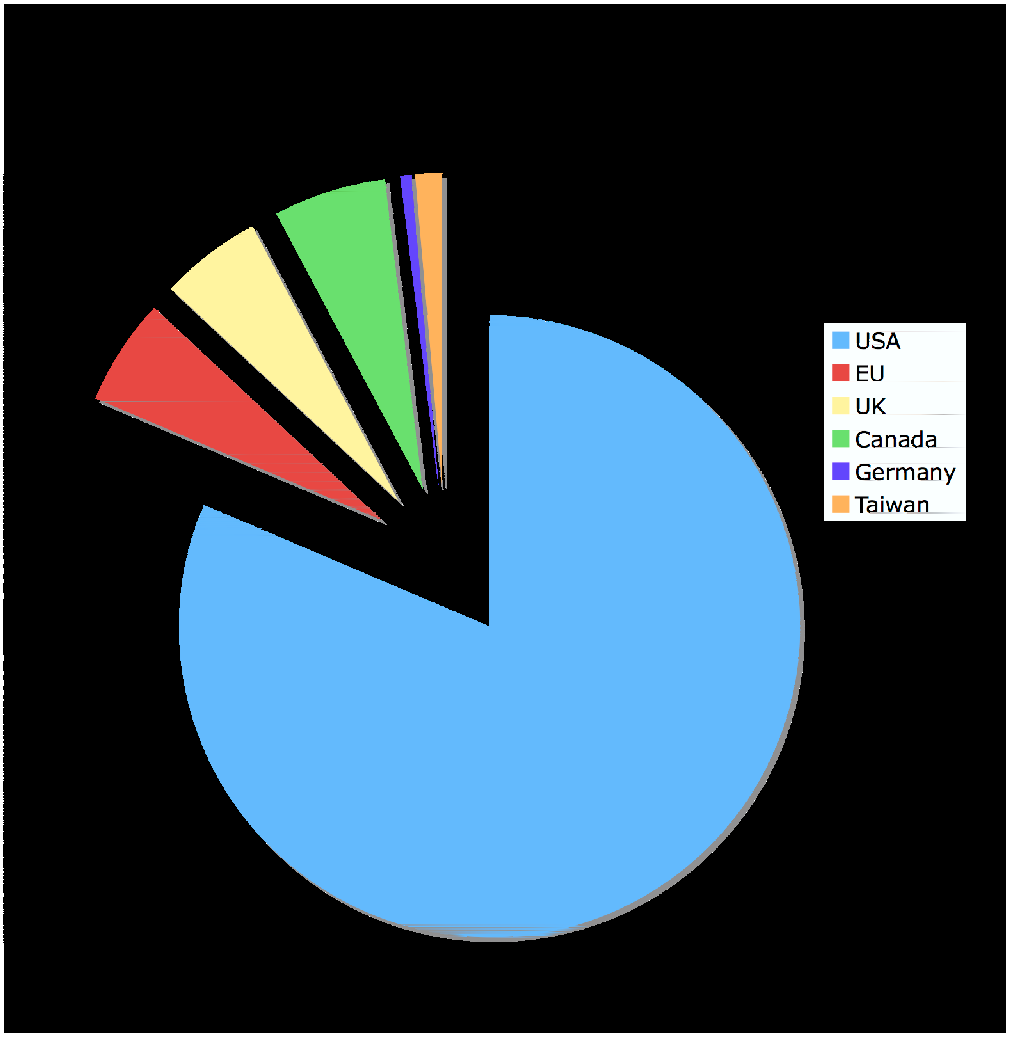
[1] Data analysis is as of November 23, 2005. The current inventory is comprehensive, but not complete. Data known to be under-represented include project-specific funding within NIOSH (which was not released by the agency), and detailed information on nanomaterials-specific projects within the National Toxicology Program. In most cases, data have been presented on project numbers and estimated annual funding; taken together, these present a clearer picture of current research than either one in isolation.

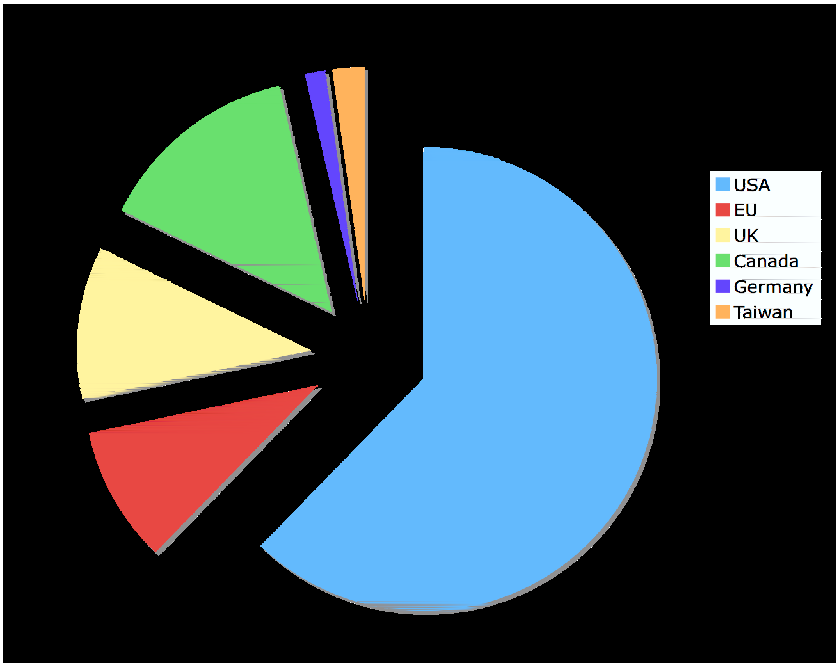
**Figure 1:**
**Total Number of Projects—By Country/Region**

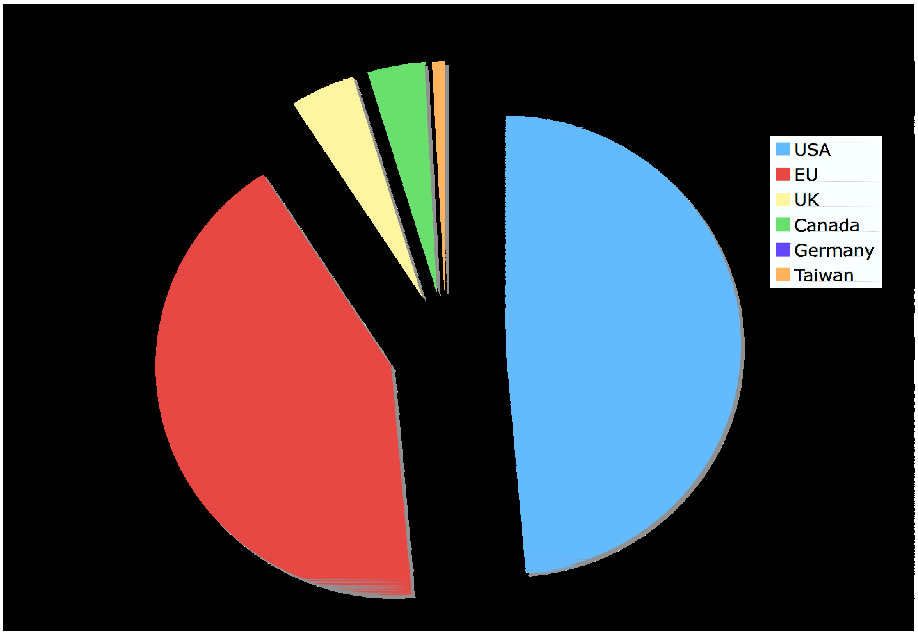



Note: Total number of projects: 208. All research projects with some relevance to nanotechnology (including research focused on incidental and natural nanoparticles) have been included.

**Figure 2:**

**Number and Funding of Highly Relevant Projects on Engineered Nanomaterials—By Country/Region**

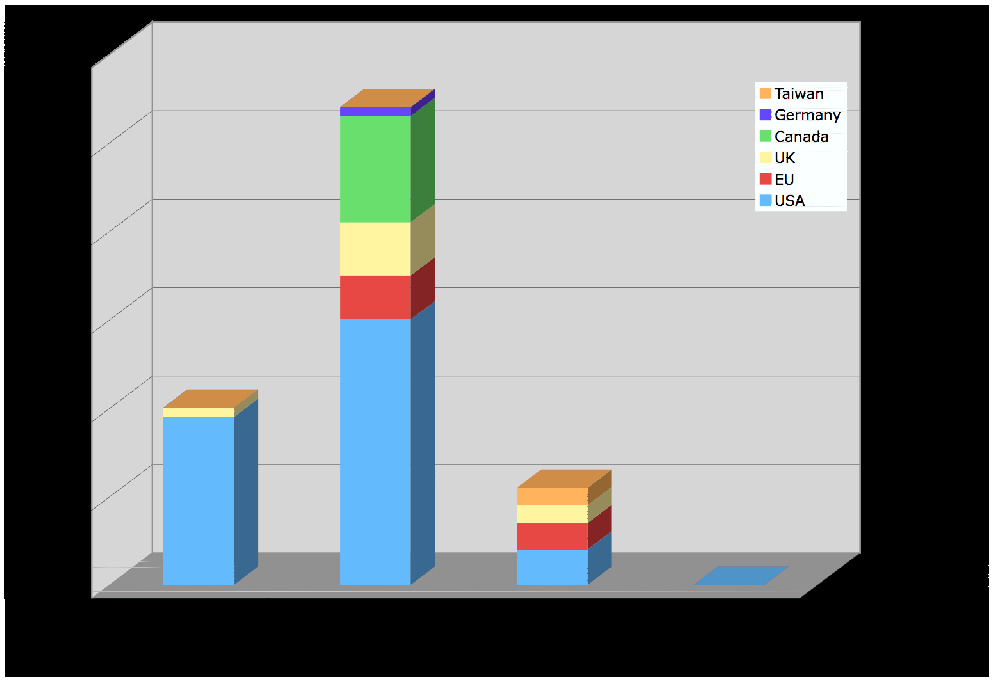


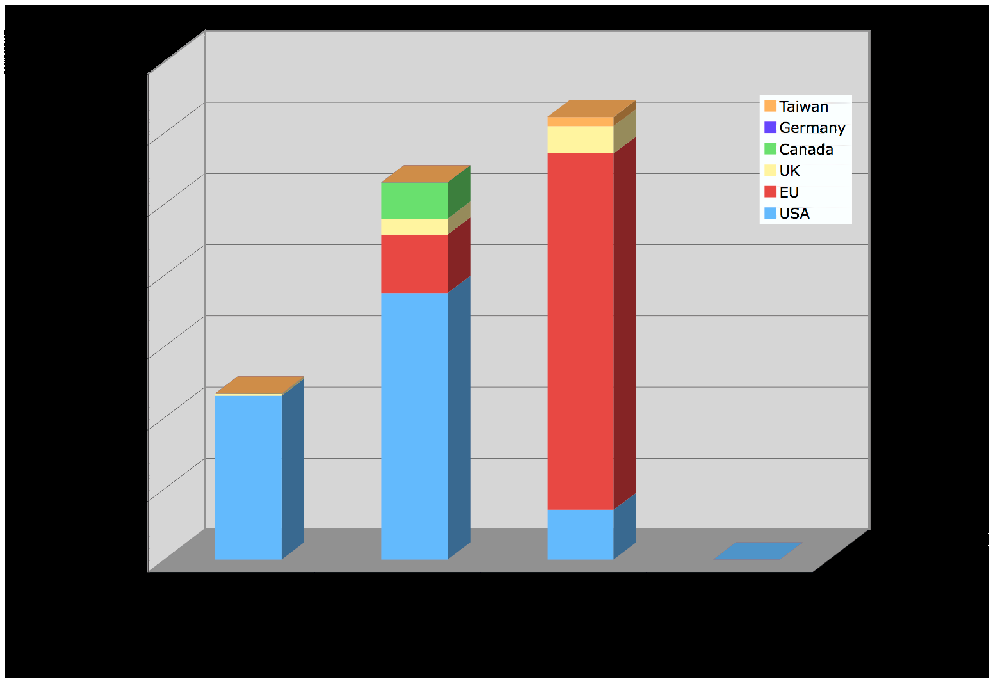




Note: Estimated annual funding for 2005 is shown (total: $14 million). Number of projects: 85. Project-specific funding information was not available from some sources, including intramural research at the National Institute for Occupational Safety and Health.

**Figure 3:**

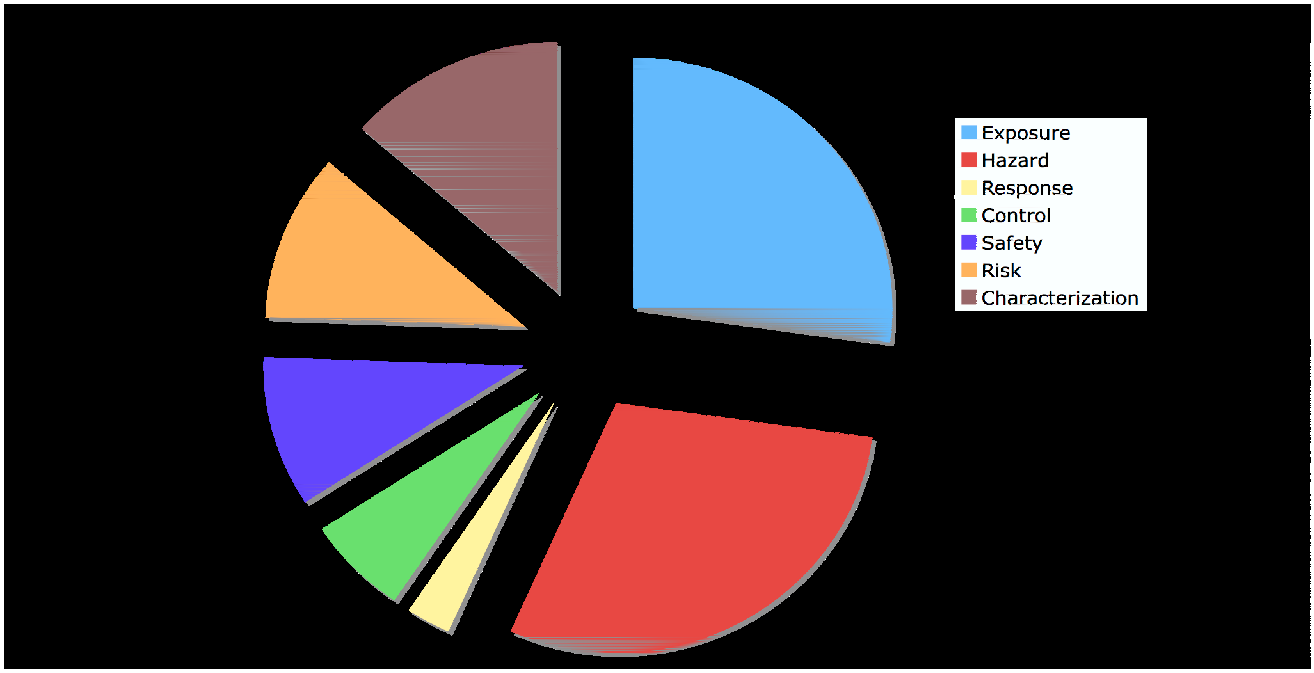
**Number and Funding of Highly Relevant Projects on Engineered Nanomaterials—By Impact Sector and Country/Region**

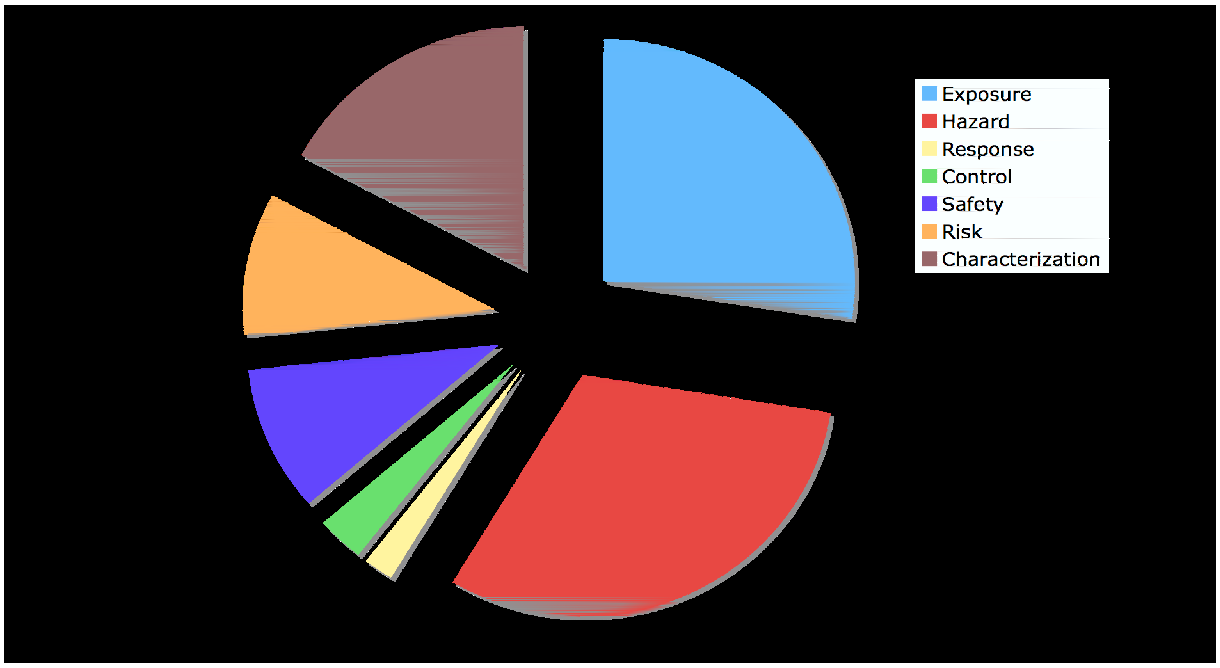



Note: Estimated annual funding for 2005 is shown (total: $14 million). Project-specific funding information was not available from some sources, including intramural research at the National Institute for Occupational Safety and Health in the US. Cross-cut funding is dominated by the NANOSAFE 2 project in Europe, which has relevance to both human health and environmental impact.

**Figure 4:**
**Number and Funding of Highly Relevant Projects on Engineered Nanomaterials in the United States—By Research Focus**

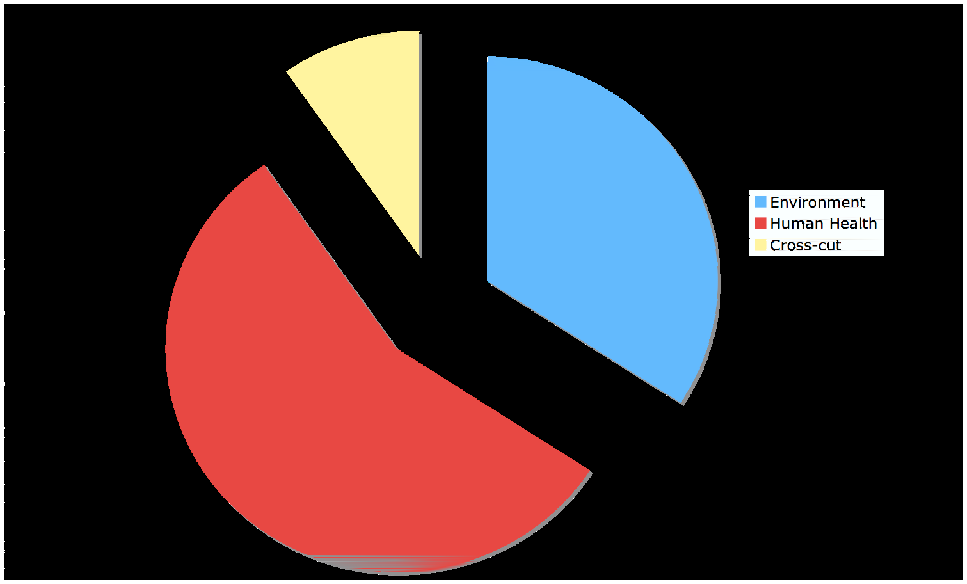



Note: Estimated annual funding for 2005 is shown. Project-specific funding information was not available from some sources, including intramural research at the National Institute for Occupational Safety and Health in the US. Where projects have relevance to multiple research foci, they have been accounted for multiple times.

**Figure 5:**

**Number and Funding of Highly Relevant Projects on Engineered Nanomaterials Hazard in the United States—By Implication Focus**

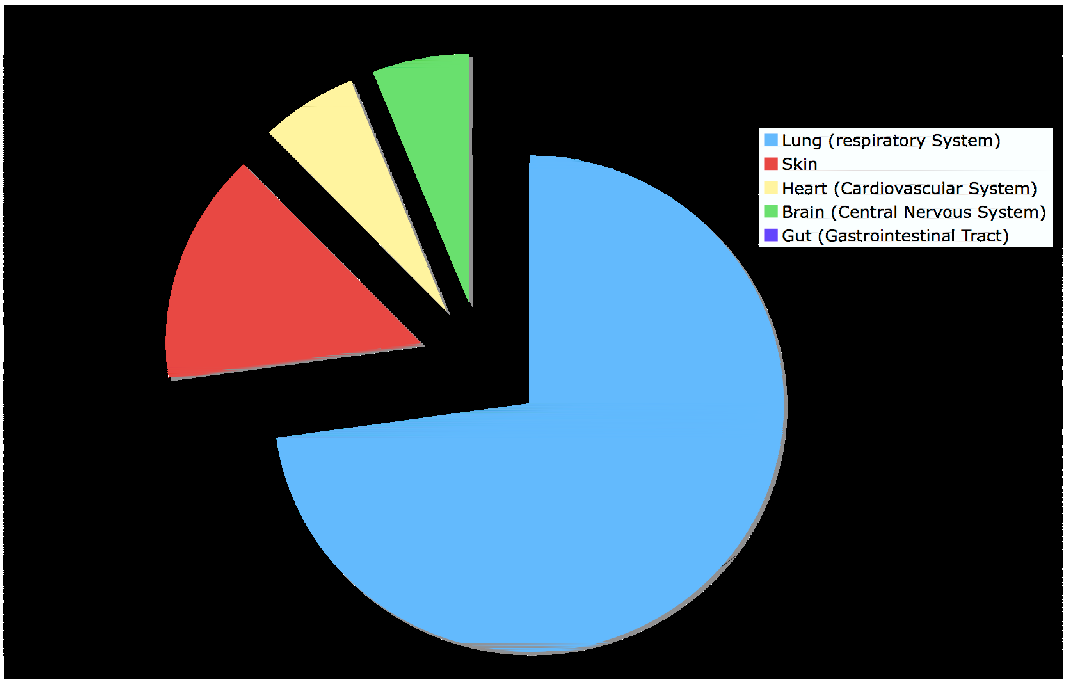


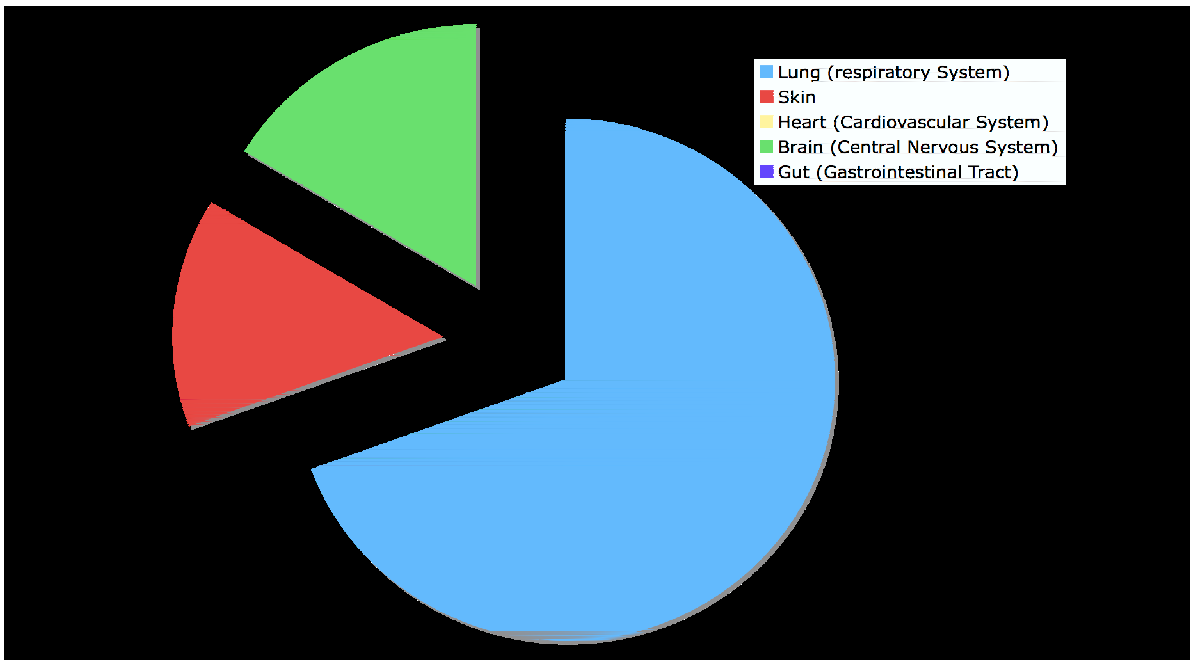


Note: Estimated annual funding for 2005 is shown (total: $5.3 million). Project-specific funding information was not available from some sources, including intramural research at the National Institute for Occupational Safety and Health in the US.

**Figure 6:**

**Number and Funding of Highly Relevant Projects on Engineered Nanomaterials Hazard in the United States—By Specific Organ**




Note: Estimated annual funding for 2005 is shown (total: $3 million). Project-specific funding information was not available from some sources, including intramural research at the National Institute for Occupational Safety and Health and the National Toxicology Program

## Supplemental Information

### Data quality

Information within the inventory has been collected from publicly available sources and provided by individual investigators. Research has been categorized by principle investigators and research managers, along with staff at the Project on Emerging Nanotechnologies. Every effort has been made to ensure that the information is accurate, although accuracy cannot be guaranteed. Although we aim to ensure that this inventory is as comprehensive as possible, there will be gaps in the data. As new information is made available, the inventory will be updated on a regular basis. Users are encouraged to submit new or updated information to nano@wilsoncenter.org.

### Scope of inventory

This inventory is designed to catalogue information on research that has some degree of relevance to the EH&S implications of nanotechnology. It is not the intention to include research which has no clear relevance to EH&S implications. Interpretation of relevant research predominantly lies with those providing information, although new entries submitted to the Project on Emerging Nanotechnologies are, and will be, evaluated prior to posting. However, the National Nanotechnology Initiative definition of implications-relevant research is suggested as a guide:

*Research and development (R&D) on the environmental, health, and safety (EHS) implications of nanotechnology includes efforts whose primary purpose is to understand and address potential risks to health and to the environment posed by this technology. Potential risks encompass those resulting from human, animal, or environmental exposure to nanoproducts-here defined as engineered nanoscale materials, nanostructured materials, or nanotechnology-based devices, and their byproducts. (www.nano.gov)*

In addition, we encourage the addition of applications-based research that has some clear relevance to understanding the implications of nanotechnology. For example, research into the development of quantum-dot based particles for medical imaging that also addresses the potential toxicity of these particles would be included, as would research into therapeutics-based mechanisms that shed light on biological interactions that could potentially lead to harm. However, applications-based research with no clear focus on EH&S implications would not be considered relevant.

### Estimated annual funding

Annual funding is estimated within the inventory where information on funding is available. This estimate is based on total project funding divided by project duration, and it may not be a true representation of expenditure within a given year. Care must be taken in interpreting funding figures, as information is not available for all projects. Some agencies have not released project-specific funding information on their intramural research programs.

**Classes of nanomaterials**

***Engineered nanomaterials***: Manufactured materials with engineered structure between approximately 1 nm and 100 nm.

***Incidental nanomaterials:*** Materials with a structure between approximately 1 nm and 100 nm that are produced as a by-product of a process. For instance, welding fume and diesel emission particulates would be considered incidental nanomaterials.

***Natural nanomaterials:*** Materials with a structure between approximately 1 nm and 100 nm that are a result of natural processes. Some particles arising from volcanic emissions, sea spray, and atmospheric gas-to-particle conversion would be considered natural nanomaterials.

***Generic:*** Research that is applicable to the EH&S implications of all nanomaterials, irrespective of class.

**Relevance of research**

Research is classified has having high, substantial, some or marginal relevance to the EH&S implications of nanotechnology. These are "fuzzy" categories, reflecting the complexity of categorizing research relevance. However, the following can be used as a general guide:

***High:*** Research that is specifically and explicitly focused on the health, environmental and/or safety implications of nanotechnology.

***Substantial:*** Research that is geared towards nanotechnology-based applications or developing fundamental new knowledge on nanoscience but that has substantial and explicit relevance to EH&S implications.

***Some:*** Research that is focused on the application of nanotechnology and developing fundamental new knowledge on nanoscience but that has some relevance to EH&S implications.

***Marginal:*** Fundamental nanoscience and/or nanotechnology applications-based research, which informs understanding on potential EH&S implications in some way.

**Broad Research Categories**

Research has been categorized into nine broad categories that are related to risk assessment and management. Multiple categories may apply to research projects:

***Exposure:*** Research on exposure to nanomaterials, including human exposure and environmental exposure. This category covers exposure evaluation but not methods development (which comes under *Characterization*).

***Hazard:*** Research associated with the hazardous nature and hazard potential of nanomaterials, including human toxicity and ecotoxicity.

***Response:*** Research into the environmental and human health response to, or impact from, exposure to nanomaterials. This category includes epidemiology and environmental impact studies.

***Generation, dispersion, transformation, etc.:*** Research into the physical, chemical (and some biological) processes that potentially influence the impact of nanomaterials on the environment or human health. This category includes research into material generation and release, transport, accumulation, and physical/chemical transformation.

***Safety:*** Research into aspects of nanotechnology which may potentially lead to physical injury—for instance, fire or explosion hazards.

***Control:*** Research relevant to controlling the release of nanomaterials and controlling exposure to nanomaterials.

***Characterization:*** Research into the characterization of nanomaterials related or relevant to exposure, hazard, response, and control studies.

***Risk assessment:*** Development and application of quantitative and qualitative risk assessments for nanotechnology/nanomaterials.

***Risk management:*** Development and application of risk management models and frameworks for nanotechnology/nanomaterials.